the research engineer

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contents

the cover

Alexander R. Ortell, an Aeronautical Engineering master's degree candidate, is shown calibrating Georgia Tech's recently-completed low-turbulence wind tunnel. The new tunnel, designed by Dr. Arnold L. Ducoffe, associate professor of Aeronautical Engineering—was constructed by Tech personnel. After it is calibrated for turbulence and velocity distributions, the tunnel will be used as a fundamental research tool for studies of the properties of laminar and turbulence boundary layers. The test area measures 42 by 42 inches and is 20 feet long. This is just one of the new facilities for aeronautical engineering education and research at Georgia Tech. For a look at the rest, turn to page 8 of this issue.

Cover photo by Cecil Allen, of the Engineering Experiment Station

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the president's page

"The man in the laboratory is the man of the hour, the decade, and the century. For scientific research, more than any one thing, has created modern America. It is responsible for its prosperity . . . way of living . . . industrial and military strength. And it promises to hold the key to the Nation's future—and survival." Richard Rutter, New York Times, Industrial Section, Jan. 2, 1957.

THE CONCEPT OF RESEARCH as we know it today stems directly from our institutions of higher learning. Long before American industry expressed much interest in research, it was a vital part of the basic mode of operation of our colleges and universities.

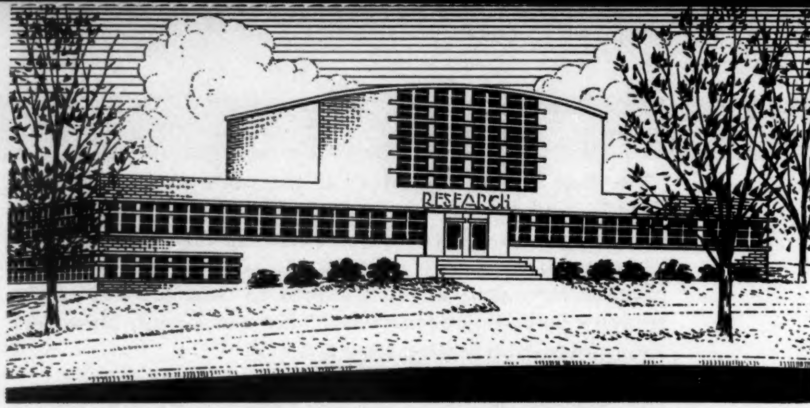
But organized industrial research is but a half-century old. It had its beginnings in the early 1900's when a man named Dr. Robert K. Duncan conceived the idea of an independent research organization to supply technical personnel and facilities for the solution of industrial and scientific problems on a contract basis. Through the financial aid of the Mellon brothers, he created the Mellon Institute.

Following Dr. Duncan's lead other such organizations sprung up all over the country. Some of them—like the Mellon Institute—were independent research agencies. Others—like our own Engineering Experiment Station—were an integral part of an educational institution. But all of these organizations had two things in common: a dedication to the cause of basic scientific research for the benefit of all mankind and a capacity for industrial research—the solution of technical problems for industrial firms who were unable economically to maintain their own research laboratories.

The growth of both of these types of research organizations has been as phenomenal as their influence on our Nation mentioned above by Mr. Rutter. Today, more than 250,000 persons derive their livelihood from direct work in research, a business that now totals over 4 billion dollars.

Georgia Tech is proud of the part that its research contributions—largest in the engineering and industrial fields in the South—have played in the industrial development of our State and region. Given the opportunity, we hope to make even greater contributions in the future.

Paul Weber
Acting President



GEORGIA TECH'S RESEARCH BUILDING, THE CENTER OF ITS INDUSTRIAL RESEARCH ACTIVITIES.

Industrial Research and Georgia Tech

By Frederick Bellinger, Assistant Director, Engineering Experiment Station

FOR YEARS, many of the industries of the South and the Georgia Tech Engineering Experiment Station have been growing through working together in research. Today, over 90 industrially sponsored projects are underway in the South's largest engineering and industrial research organization.

In view of the widely publicized movement of industries into Georgia as well as the growth of the existing industries, it is almost inevitable that this research will grow. For, the rate of effort to date is but a small fraction of the work which could be going on if our regional industries take advantage of the facilities at their doorsteps to insure a continuous growth of prosperity.

It has been pointed out many times that an industry must grow by simple expansion or by diversification of products in order to stay alive in an industrial atmosphere of expanding economy. Research is the insurance that an industry will survive.

The word research simply means "to study closely." In most cases it requires only cooperation between the trained researcher and the business man to transform the results of this study into practice. Properly carried out, reseach processes do not fail. Results may be negative, showing that further work should not be done, but to say that such a result is a failure is incorrect.

Research and growth

Scientific research, both basic and applied, has had a great deal to do with the advancement of our modern technological civilization.

Research creates new products and new uses for old products. Eighty-five percent of today's farm chemical business involves chemicals that were not available just 10 years ago. Ninety percent of today's prescriptions use medicines that did not exist 15 years ago. Of 8,000 chemicals listed in a recent catolog, 2,900 of them did not appear in the catolog published by the same firm only 12 years ago.

Research creates new jobs. Typical examples show that one new chemical production worker creates about four jobs in other manufacturing plants and about 20 new jobs including retailing.

Research conserves material . The in-

creasing use of thiocarbamates in place of copper compounds in controlling fungus diseases of agricultural crops has released millions of pounds of copper for other uses, as well as doing a better and cheaper job.

Research conserves health. The discovery of such new drugs as the sulphur compounds in 1935 and penicillin in 1942 has had remarkable success in decreasing the death rate in this country as well as shortened the disability days of people suffering from infectious diseases.

All these factors help create a higher standard of living for everyone.

Industrial research today

There are three basic reasons why industrial research is being carried out in this country: (1) to develop new products in order to diversify lines and gain an advantage over competitors (roughly half of the research dollars goes in this direction), (2) to improve the equality and uniformity of products and processes and to lower cost of production (forty to fifty percent of the research dollar is spent in this field), and (3) to obtain basic data on properties and reactions, leading to more complete knowledge of what is being produced and what might be produced (United States' industries spent on the average of about 8 to 10 percent of its research dollar in this field).

Chart number 1 is referred to quite often by people selling research. The quick conclusion drawn from the chart is that an industry spending more money on research is assured of a higher growth rate. Producers of a few stable items in, for example, the raw materials class, are perhaps justified in appropriating as low as one percent of their net sales dollar for research. Other industries having products subject to early obsolence are justified in spending 5 percent or more of the net sales in new product development and research.

Small industries usually start with research on their existing products and feel that they themselves are best qualified to do it. This may be true in most cases, but it should not be overlooked that a fresh viewpoint obtained from outsiders can develop novel ideas which may be just the answer to a difficult problem.

Individuals and small industrial firms are turning to "study" centers such as the Engineering Experiment Station with problems that require the attention of experts in more than one field. Cooperative research, with the cost and profits shared by an association of industries, is becoming more and more popular due to rising costs and a severe shortage of men trained and capable of undertaking research work. It is not easy to sell competitive industries on the benefits of cooperating in research, yet much is to be gained through this method.

A few years ago a growing surplus of tallow and greases faced United States' renderers. On the west coast, 25 companies, each feeling too small to underwrite a research program, formed Tallow Research, Inc., and employed a research institute to undertake research for them. Within 2 years, new products were developed using tallow as a raw material. Consequently, new markets were opened for the disposal of the surplus. This is, as it should be, a somewhat typical rather than an unusual example.

The success of cooperative research by industry depends only on the common problems of commercial importance, active cooperation and participation by the cooperative members, and a guiding committee or group to see that the research results are translated efficiently into practice.

Georgia Tech's research

The Engineering Experiment Station—one of Georgia Tech's largest divisions—was authorized by the State Legislature in 1919 for the purpose of promoting and furthering engineering and industrial research and aiding in the economic development of the State and the region.

As an integral unit of Georgia Tech, the Station can arrange for the services of many experts to supervise and carry out research projects. The members of Tech's teaching faculty—trained in many diverse fields—are ideally suited to carry out both sponsored and basic research.

Continued on page 6

Today, the Station employs around 70 teaching faculty members to aid in the planning and execution of many of its research programs. Because this teaching staff is not available for full time research work, the Station has had to build up a sizeable force of qualified research specialists. Bolstered by nearly 200 technical and administrative assistants, these scientists and engineers work on studies varying from such projects as development of an automatic yo-yo assembling machine to wave quide development, radioisotopes research and the investigation of a new series of chemical reactions.

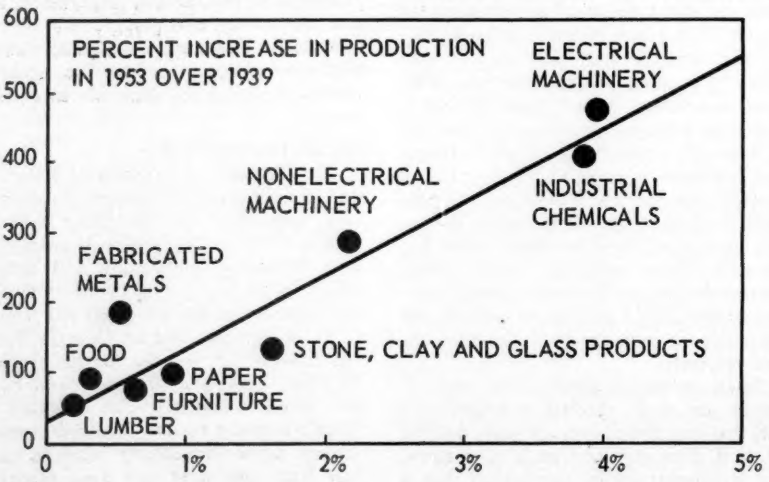
One of the byproducts of research is the protection giving the sponsor by patents. Georgia Tech's research policy gives all patent rights to the individual sponsor. Publication of information as well as prosecution of a patent is under the complete control of the sponsor.

In some cases, Tech may work with industry on a cooperative basis, financially, and the division of benefits is agreed upon prior to starting work. Normally, however, the benefits to Georgia Tech are in the area of broadening its contacts, interests, and experience of its personnel and in the discharge of one of its basic responsibilities—to assist in the economic development of the region.

It is not necessary to extol the breadth and capabilities of Tech's facilities and personnel in the sciences or on the football field. But it may not be so well known that the Engineering Experiment Station has several branches with the specific responsibility of working with industry.

The Industrial Development Branch is one such operation. It operates in the field of industrial economic research—assimilating, correlating and analyzing the facts needed to assess the industrial potential of the state and region. It also is charged with determining what industries possibly can be developed or expanded and to assist established industries to become more efficent or more productive. It eventually will work in area development, energy economics, nuclear economics, water economics, market research, company organization and development, manpower utilization, operations research, production research, engineering economics and even agricultural economics.

CHART 1—CORRELATION OF RESEARCH EXPENDITURES AND GROWTH RATE OF INDUSTRIES.



Another branch is the Industrial Products Branch of the Chemical Sciences Division. This is a laboratory experimentation group staffed to permit feasibility studies on materials and processes. In other words, its responsibilities are to answer the questions "Will it work?" or "Is it any good?" or, "How should it be made?" Still another branch is the Technical Information Section. This group collects, compiles, digests, and reports technical information. Its work can be a single item study, a specific technical field study, or a continuing service to furnish the sponsor a considered abstract of information as it appears.

Sponsored research

The Engineering Experiment Station operates through the Georgia Tech Research Institute (GTRI), a non-profit organization incorporated to serve as the Station's contractual agency.

Tech's sponsored research is done on a project basis. Usually the person, or persons, with a problem comes to the Station for preliminary discussion. At this time, the problem is clarified, and it is specified that the Station can accept work only if it involves research of a type not suitable for industrial or professional consultants in the region. In addition, this work must be within the interest, capabilities and responsibilities of the Station.

On the basis that cost estimates and all other phases are mutually acceptable, an agreement is signed and a scientist or engineer is assigned as a project director. This man will have full responsibility to see that the research is conducted properly and that the sponsor is kept advised through reports, verbal or oral, as agreed upon. The sponsor receives bills for actual expenditures for personnel and materials, etc., on the project. Overhead charges for use of the facilities, power, water, procurements and other office and administrative expenses are based on a percentage of the direct personnel charges. No charges in excess of the amount initially agreed upon can be made without prior approval of the sponsor. This system protects the sponsor from unexpected expenses and in many cases results in the total cost to the sponsor being less than estimated.

TITLE:	
SCOPE:	**Objectives—sources of information Time, Costs, patents, probability of technical success.**
MARKET DATA:	**Total market competition, applications, % at market available to us.**
PLANT DATA:	**Plant capacity, construction completion date.**
CAPITAL REQUIREMENTS:	**Plant investment, working capital cost of production $/lb.**
ECONOMIC EVALUATION:	**Price, sales volume, net profit return on investment.**
RAW MATERIAL REQUIREMENTS:	

TABLE 2—RESEARCH PROJECT EVALUATION

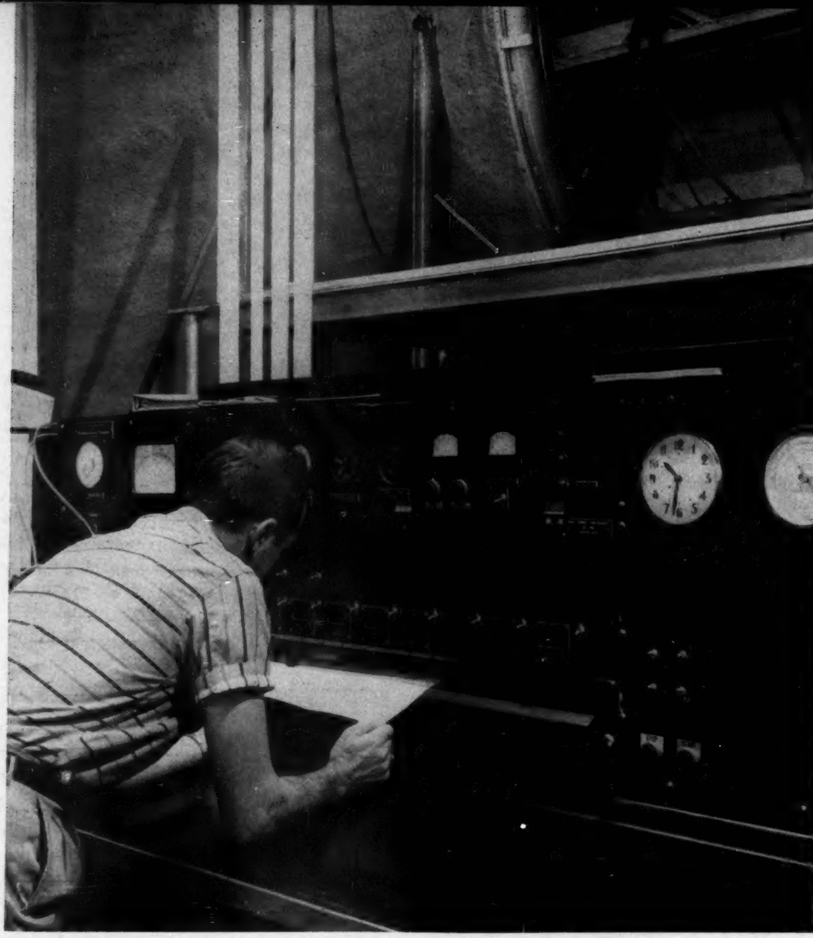
Applied research decisions

Many suggestions, mathematical equations, evaluation charts, etc. have been proposed as quasi-scientific methods of determining whether or not a research project should be initiated as well as the degree of urgency. But in the final analysis, the decision is based upon the judgement of the executive who may, or may not use one or more of the equations to assist him in clarifying the picture.

Obviously, preliminary research, such as a feasibility study, does not require complete detailed data, but the Engineering Experiment Station believes it best to make rough *guesstimates* on the phases noted in Chart Number 2 before spending the sponsors money.

For small applied research items, one rule that may be applied with caution is that the estimated net return must equal to or exceed three times the estimated research cost before the decision is made to go ahead with the project.

Fortunately, in today's research world, it is a relatively rare thing to find such small returns indicated. Research has proven itself over the past 30 years to be one of the best investments industry can make. And this area has yet to really scratch the surface of its own potential.



THE RENOVATED CONSOLE WITH READOUT PRINTER OF TECH'S 9-FOOT WIND TUNNEL

TECH'S NEW AERONAUTICAL RESEARCH FACILITIES

by Donnell W. Dutton, Director School of Aeronautics

THE NINE-FOOT low-speed wind tunnel, located in the Gugenheim Building on the Georgia Institute of Technology campus, was completed in 1934 and has undergone many modifications since that time to improve and extend its operating range and performance. During the second World War, and immediately thereafter, the tunnel was run on a two-shift, six-day a week basis and tested such famous airplanes as the XB-48 Jet Bomber, the XP4M-1

Navy Patrol Bomber, the Martin 202 transport, and McDonnell XF-88. It has also tested a variety of other items, some of them—like boats, signboards, water towers, and ventilators—seemingly unrelated to aeronautics.

At first glance it would seem that the need for low-speed wind tunnels would be greatly reduced with the advent of the supersonic airplane and jet propulsion. However, even these airplanes must land and take off at slow speeds, so their configurations must be tested under these conditions. In addition, the helicopter and the newer so-called VTOL (vertical take-off aircraft) operate almost continuously below one-hundered and fifty miles an hour. Thus, the low speed wind tunnel is still a very useful piece of equipment as long as it is large enough to handle the models and produce what is known as a reasonable Reynolds Number —roughly the product of the speed times the dimension parallel with the wind velocity.

As the Lockheed Marietta Division grew both in size and scope, their need for low-speed wind-tunnel facilities increased. Fortunately, the Georgia Tech wind tunnel, if kept up-to-date, is of sufficiently large size to make its continued operation useful. In 1954, the Institute and Lockheed began to discuss the advisability and feasibility of changes in the wind tunnel. These discussions were culminated in January of 1955 with the signing of a contract that amounted to Lockheed's purchasing eighty-three thousand dollars worth of wind-tunnel time in advance so that the money for the improvements would be available. Lockheed has given some ten thousand dollars additional in the way of materials and services, while the Institute has put in slightly more than this in similar services and in materials. From the completion of the modification program in September of 1956 to the present time the tunnel has been used exclusively by Lockheed .The Kaman Aircraft Corporation of Hartford, Connecticut will start their first test in February. The facilities, of course, are available to anyone else desiring their use, and time is available for this purpose.

The improvements and changes during the latest modification program consist of relocating the fan to a more efficient location, the redesign of the fan housing and drive, the modification of the fan itself, a new and more powerful drive system with electronic speed control, a redesigned test section and throat contraction to improve the flow in the test section, new weighing equipment, and new read out equipment including a printer. Thus it is no longer necessary to read the dials. You merely push a button and all of the forces, moments, and angles are printed.

In addition to the large wind tunnel, Tech's Aeronautical Engineering School contains a small thirty-inch square throat wind tunnel used primarily for student instructional purposes but also suitable for a minimum amount of graduate research; a low-turbulence wind tunnel with a test section 42 inches square and twenty-feet long that will be used in basic research studies of laminar and turbulance boundry layers; a structure laboratory which contains a special forty-thousand pound Universal testing machine, a Sontag fatigue testing machine, and miscellaneous strain gage and stress equipment.

The compressible flow laboratory consists of an air supply, fillers, dryers, and storage tank so that a variety of programs can be handled. The A. E. School's greatest need is probably the expansion of this laboratory. At the present time the storage capacity is limited and only a small two-inch by four-inch supersonic wind tunnel is possible. Plans for the expansion of this laboratory are underway. The first part of the building itself will be completed before the end of the summer of 1957, but money is needed for additional compressors, tankage, and dryers, as well as the larger supersonic tunnel with its associated optical and electronic equipment. It is hoped that the new laboratory will be air conditioned and provision has already been made for inclusion of silencing towers as necessary.

PROFESSOR ROBERT ALLEN AT THE FUEL INJECTION SYSTEM IN THE NEW RESEARCH AREA

Mechanical Engineering Research Facilities

By William B. Harrison, III, Professor of Mechanical Engineering

THOUGH THE NEED for a research facility in Georgia Tech's School of Mechanical Engineering has long been recognized, it was the summer of 1953 before the initial development of the Heat Transfer Laboratory—first milestone in that direction—was undertaken.

The usual shortages of space, tools and instruments, and financial support were the deterrents to an earlier development of the laboratory. To acquire the needed space, arrangements were made to move the surplus equipment stored in a small frame building west of the Mechanical Engineering Building on the main campus. This space made available for the Heat Transfer Laboratory was approximately 50 feet long by 20 feet wide. The cement pad floor was sloped suitably for draining, and the height between the floor line and the ceiling was 12 feet. Large doors on one end of the Laboratory permitted easy access for bulky equipment.

Most of the hand tools commonly needed for this type of a laboratory were provided by the School of Mechanical Engineering, but research tools such as potentiometers, galvanometers, etc. were in very meager supply. As this expense and additional financial support were beyond the capacity of the School of Mechanical Engineering, the Engineering Experiment Station was called on for help. If the Station could through its research contacts find outside sponsors interested in research in the heat transfer field, a sound basis would be provided for the Station to furnish funds to develop the new research facilities. With this in mind, several research proposals were generated for consideration by sponsors. They included such subjects as: (1) Wetting effects on boiling heat transfer, (2) Convective heat transfer in entrance regions, (3) Effects of acoustic vibrations on convective heat transfer, (4) Heat

transfer to molten sodium, (5) Thermal diffusivity determinations in gases or vapors by a cyclic heat transfer method, (6) Determination of the viscosity of steam, and (7) A vapor tunnel analog for supersonic wind tunnels.

The study of wetting effects on boiling heat transfer became the first sponsored project in the Heat Transfer Laboratory. It was financed by the Office of Ordnance Research, U. S. Army, and some additional phases of this initial project are still being explored.

From this beginning, the Heat Transfer Laboratory advanced in its first year to the position of a stable and very busy research area. Following the sponsorship of the study on boiling by the Office of Ordnance Research, the National Advisory Committee for Aeronautics undertook sponsorship of the study on effects of acoustic vibrations on convective heat transfer. The American Society for Mechanical Engineers is supporting the research proposals for determining thermal diffusivity and viscosity of vapors. The Office of Ordnance Research is supporting the study involving molten sodium. The study of entrance region heat transfer was started on a limited basis without outside sponsorship. It may be extended later on a sponsored basis. Another study made without sponsorship concerned the feasibility of using rocket thrust motors to attain hypersonic flow in nozzles.

With this show of interest in heat transfer research, the Engineering Experiment Station and the School of Mechanical Engineering were able to provide the Laboratory with additional services and apparatus. The Laboratory was supplied with water, steam, compressed air, and natural gas service. Oscilloscopes and other electronic equipment, potentiometers, galvanometers, and other apparatus for precision measurements. A small stock of hardware items such as nuts, bolts, and valves was assembled and a file of industrial literature and catalog information was set up.

The research activities developed so rapidly that the Heat Transfer Laboratory was soon in need of more space and more staff. It actually became necessary to decline to submit proposals on heat transfer research requested by outside agencies because of limitations on space and staff time.

With the new laboratory as a starting point, the School of Mechanical Engineering was in a position to seriously expand the heat transfer research and develop other fields of research interest. The other general fields of immediate interest were fluid mechanics, thermodynamics and internal combustion engines. Coincident with this need for expansion of the research area were two important developments in the school of Mechanical Engineering.

1. The School of Mechanical Engineering developed and presented a program leading to the degree of Doctor of Philosophy. This gives a strong motivation to the faculty of the School of Mechanical Engineering to supervise many

continued on page 12

Dr. William Harrison, left, and Win Boteler work in the old heat transfer laboratory, predecessor to the new ME research labs.

The research area of the new ME laboratory. Today, projects are being carried out in viscosity studies, liquid metals, boiling heat transfer, thermal properties of certain gases, fuel injection systems and other areas.

mechanical engineering—cont.

of the sponsored research projects which could be used in part as thesis material. Furthermore, the graduate students in this advanced program are able to serve as research staff and research assistants and, in many cases as teaching staff or teaching assistants. The doctorate program and the expanded research activity complement each other quite well, and the limitation on staff should be relieved as the program develops.

2. Laboratory work by students in pattern making was discontinued in the School of Mechanical Engineering. This created a solution to the space limitation by making the entire Pattern Laboratory available for Methanical Engineering Research. The wood working equipment of the Pattern Laboratory was consolidated in the building which has been occupied by the Heat Transfer Laboratory, and it is now being referred to as the Pattern Shop. The heat transfer activities have been moved into the space which had been occupied by the Pattern Laboratory, and it is now referred to as the Mechanical Engineering Research Laboratory.

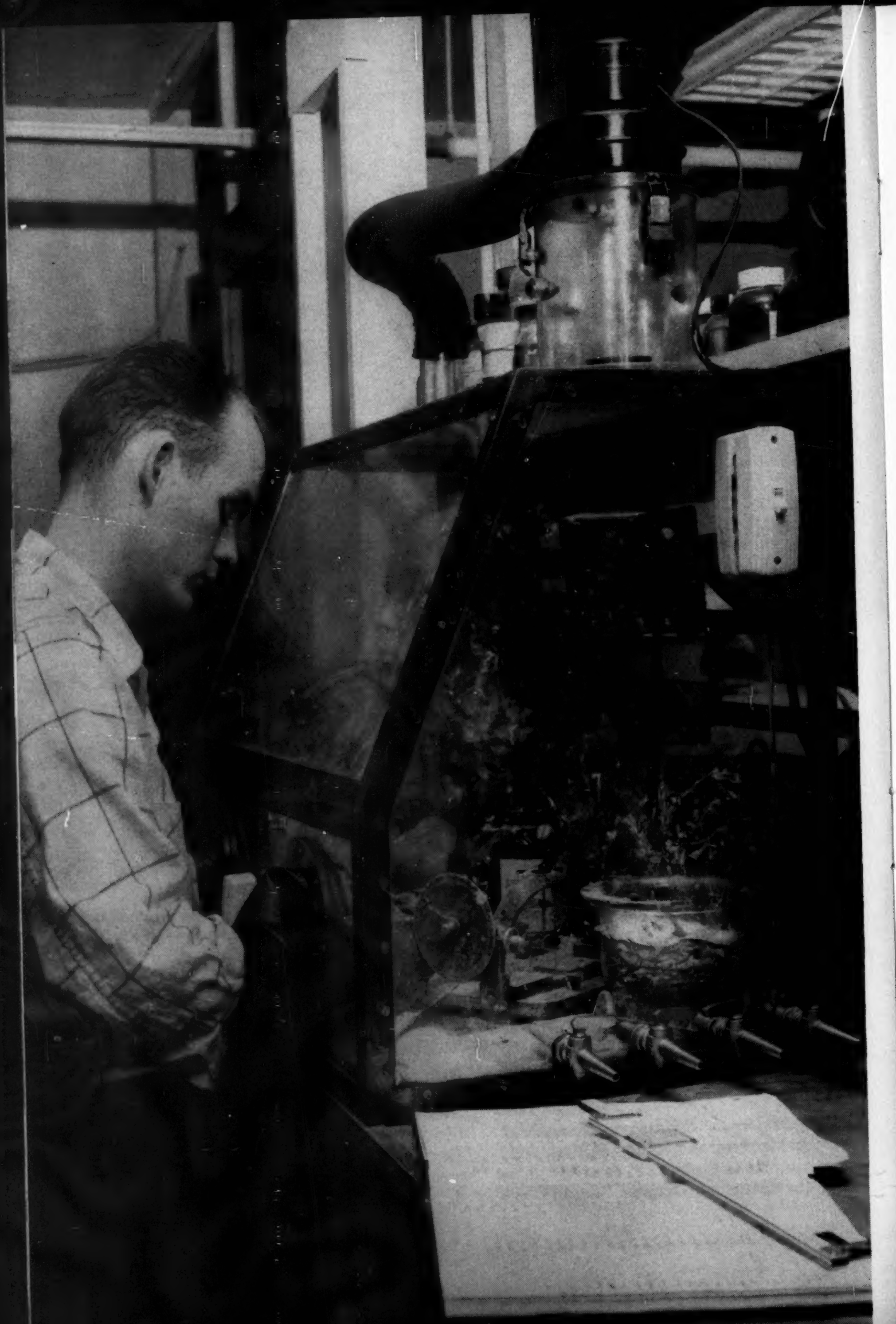
The Mechanical Engineering Research Laboratory is a sheet metal structure on a steel frame with concrete floor and foundation. The overall dimensions are about 67 by 92 feet. There is a clear span of about 30 feet through the center of the building equipped with an overhead crane. A sum of $30,000 was made available for revising the building to conform to its new functions. The revisions have been completed. Generally, here are the features of the new laboratory: (1) Services such as electricity, low pressure steam, compressed air, water and natural gas at strategic locations with a hope of high pressure steam in the near future . . . (2) an instruments laboratory for research on instrumentation, instrument calibration and instrument storage . . . (3) a small physical properties laboratory for chemical or physical testing, small-scale experimentation and related material storage . . . (4) a small machine shop and tools for on-the-spot work and small jobs as major machine work is done in the Mechanical Engineering shops or the Station shops . . . (5) office space and lockers for those who have major projects in the laboratory . . . (6) a well-equipped general purpose room for seminars, conferences and work and computation sessions . . . (7) a small photographic darkroom for processing oscillograph records, etc. . . . (8) a general office with industrial catalog and technical report files and a small collection of reference books pertinent to research being conducted . . . and (9) space for general research needs.

The accompanying floor plan (figure 1) and photographs give more detail on the orientation of the various features and their relative space assignments. The

basic philosophy underlying the furnishings and equipment in the building is that everything should be functional and that the facilities should permit as broad a scope of experimental operations as possible. The Mechanical Engineering Research Laboratory now offers possibilities in space and equipment for a wide scope of research problems, and may be considered as one of the major research centers on the Georgia Tech campus. It stands in its present form because of the efforts of Dr. Homer S. Weber and the cooperative assistance from others of the Georgia Tech administration. Details of the plans for developing the building have been evolved by a small group of the Mechanical Engineering staff. Much of the research equipment has come from the Engineering Experiment Station, particularly as a result of the efforts of Dr. T. W. Jackson.

The research environment, presented in the Mechanical Engineering Research Laboratory, is a powerful force in shaping the future of Georgia Tech. It will assist in bringing to Georgia Tech the graduate students and staff members needed to meet the increasing teaching needs and it will further enhance the reputation of Georgia Tech as a result of the research which is performed within it. The scope of research interests exhibited by the present staff is already expanding at a rapid rate. Present research involves such things as fuel injection systems, viscosity studies, liquid metals, boiling heat transfer and thermal properties of certain gases. Proposals for research have recently been made by the staff on problems in uses of solar energy, theoretical heat transfer and fluid mechanics, and other basic mechanical engineering subjects.

It seems to be only a matter of time until this new facility is completely filled with the magic and excitement of discovery of new ideas and principles, and new applications of old principles. An excitement that is the indispensible ingredient of a progressive, thriving academic and technical community.



Tech Research Assistant W. J. Corbett works with a controlled atmosphere chamber to establish what holds together bits of matter.

by Clyde Orr
Research Associate Professor

Aerosol Studies at Georgia Tech

In the laboratory, smoke and dust reveal some surprising properties

TO THE AVERAGE PERSON aerosols are sprays of paint, lacquor, deodorant, hair dressing, insect repellent, and the like which can be purchased in cans at many stores. To the scientist an aerosol is a relatively stable dispersion of very small solid particles or liquid droplets in a gas, a definition which covers not only the commercial items but also includes dust clouds, smokes, fogs, fumes and such.

For the amount of matter composing them, aerosols (in the broadest terminology) exert a disproportionately large influence on natural phenomena. For example, the dust in the air is largely responsible for the glorious colors of a sunset. Without aerosols there could be neither cloudburst nor shower, for each raindrop must grow about a tiny bit of matter. Industrially, understanding aerosol behavior is vital. Valuable products can be saved and, at the same time, pollution of the air with smoke and fume prevented. The farmer who dusts his crops with an insecticide can, perhaps when aerosols are better understood, see more of the agent stick to his plants and less drift away to be lost.

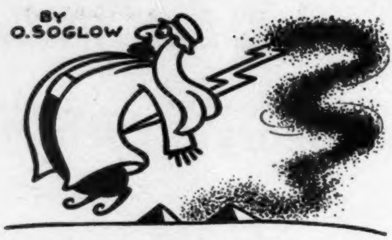
At the present time, it is no exageration that more specific information has been gained about the building block of nature molecules, atoms and electrons—than about aerosols. Chemists and physicists investigating numbers of subjects and determine with great statistical precision the mean condition or state prevailing even though their individual subjects cannot be seen. On the other hand, when these same investigators study aerosol particles which can be observed with microscopes statistically accurate results are extremely difficult to obtain. This is true because the particles differ somewhat in size, shape, and composition and only a comparatively small number of them can be observed at one time.

Since 1948, however, a series of aerosol studies has been conducted in the Micromeritics Laboratory at Georgia Tech. These have been concerned with the effects of particle size, the electric charge on the particles, the tendency of the particles to aggregate and the effects of thermal gradients, ultrasonic sounds and inertial and other forces.

Aerosols represent an extreme state of subdivision, one that greatly increases the surface area of the dispersed material and expands the space occupied by it. A solid cube one centimeter on a side has a surface area of 6 square centimeters. If this cube were divided into smaller cubes one micron on a side (0.000041 inch), the total surface area would increase to 60,000 square centimeters. If, from this powder, an aerosol were formed having 100 million particles per cubic foot of air, the 1 cubic centimeter of solid would be dispersed in 10,000 cubic feet of air.

Great chemical reactivity is associated with large surface area. Most substances will burn when finely divided and ade-

O. Soglow Art, Courtesy of Air-Maze Corporation



WHERE DUST MAKES ELECTRICITY! Dust storms on the Sahara Desert are often accompanied by frightening displays of lightning. The cause: static electricity built up by collisions between dust particles and friction between wind and dust particles.

AEROSOLS—cont.

quately dispersed. Powdered aluminum, for example, burns readily. Coal, wheat and sugar must be transported from one storage bin to another in industry with extreme caution lest the finely divided dust associated with these materials cause terrific explosions. The explosibility of sugar dust particularly has been investigated at Georgia Tech. As might be expected this property has been shown to be a function of the surface area and the chemical structure of the sugar. An outstanding property of aerosol in general is therefore extreme reactivity.

Perhaps more than any other, the electric charges on aerosol particles influence their physical behavior. Most airborn particles, whether dust, smoke or fog, have a charge on them. While aerosols differ widely in the actual distribution of charges a typical aerosol might have about 45 per cent of its particles charged negatively, about 45 per cent charged positively, and 10 per cent neutral. The charge which individual particles carry also varies widely and it decreases rapidly as particle size decreases. It depends on the conducting and dielectric properties of the particles as well as on the effectiveness of the charging source. It is rather difficult to cause a particle of one micron diameter to have a charge greater than that equivalent to a few hundred electrons, while, under the same treatment, difficulty would be experienced in getting a one-tenth micron particle to have more than a few electron charges. Actually, almost all particles have much less than this charge.

How finely divided materials come to have charges is related to some of the basic properties of matter. Smokes, products of combustion processes, arise from rather high temperature reactions generally. At the temperature involved, most materials give off electrons, the so-called thermal emission electrons upon which the operation of electronic vacuum tubes depends. Hot smoke particles thus have a good chance of becoming positively charged by losing electrons. As they move away they also may pick up some of the swarm of electrons of the reaction zone by simple collision processes. Thus, a smoke particle may obtain a net charge of either sign or, of course, if the positive charges exactly cancel the negative ones, be neutral.

Most materials have so-called free electrons which move randomly insofar as can be determined from atom to atom. Metals particularly have these electrons; they are very good electrical conductors for this very reason. At the instant when solid materials are broken apart or when materials in intimate contact are separated, there is a likelihood that more of these

DUST DEADLY AS T.N.T. Who'd guess a grain elevator could blow up like an ammunition dump? It happened in Chicago! A spark ignited dust particles in a loading tunnel—blew forty storage bins weighing 300,000 tons off their bases.

free electrons will be in one part than in the other. In dispersions of dusts some particles may have an excess of electrons while others must have a deficiency. Again, there exists the possibility that some particles will possess a net charge of zero.

Once produced, aerosols may gain charges in other ways. As is well known, the earth is continuously bombarded by cosmic radiation. This produces charged air molecules, called ions, in the atmosphere and these attach themselves to particles which chance to be nearby. Also, the earth's crust contains the radioactive elements radium and thorium. These continuously decay into the gases radon and thoron which slowly diffuse into the air, there to give up some of their energy in ionizing radiations. The quantities of these gases are quite small but a rather large number of ions is produced nevertheless.

The main effect of charge of the aerosol particles is to influence aggregation, i. e., the tendency of particles to come together in large aggregates. Visible soot particles from a coal flame are merely clumps of many smaller particles. The arrangement assumed by the aggregate is largely determined by charges on the particles involved. In many cases, there is a definite tendency for tree-like branches of particles to form. Observing such

BY O.SOGLOW

DUST DEADLY AS BACTERIA. Certain types of dust are extremely harmful to human beings. Quartz dust, for example, can sometimes lead to diseases such as silicosis, cancer and tuberculosis.

DUST CAN BE BEAUTIFUL! Airborne dust—often a nuisance to industry—is also the cause of one of the most spectacular beauties of nature! Fine dust particles in the atmosphere reflect some colors of the sunlight more strongly than others—give us our colorful sunsets.

aggregates under a high power microscope, these branches may be seen to wave back and forth as faint breezes drift by. Occasionally a branch may be seen to behave in a very "untree-like" manner: It will rotate completely as though attached by a ball-and-socket joint. This shows that the particles are not cemented together and indicates that electrical forces are holding the particles together.

It might appear that aerosols made up of approximately equal numbers of oppositely charged particles would decay rapidly due to the mutual interaction of the particles. When the concentration of particles is greater than about 10^6 per cubic centimeter this does occur; lesser concentrations are surprisingly stable. They are more stable in fact than aerosols in which all particles have the same charge. The latter aerosols tend to expand as a result of mutual electrical repulsion. When confined in a vessel, the particles of such an aerosol are precipitated on the walls rather rapidly.

The electrical charges on aerosols permitted a rather unusual measurement to be made recently in the Micromeritics Laboratory. The charge any particle may have must amount to a whole number of electron charges; there can be no half or quarter electron. Yet when measuring the charges on airborne bacteria using an approximate value for their density

AEROSOLS—cont.

(the only value known at the time) the charges obtained were consistently a little greater than the nearest whole number. Investigation showed the density was in error and permitted a calculation of the true value. This was no mean fete when it is considered that, in essence, a bacterium was weighed and that a single bacterium of the type employed weighs only about 10^{-15} lb. (0.000000000000001 lb.)

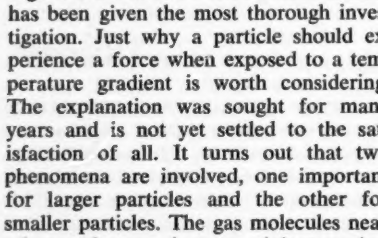
After electric properties, the movement of particles in a thermal field, i.e., in the region between a hot and a cold surface, has been given the most thorough investigation. Just why a particle should experience a force when exposed to a temperature gradient is worth considering. The explanation was sought for many years and is not yet settled to the satisfaction of all. It turns out that two phenomena are involved, one important for larger particles and the other for smaller particles. The gas molecules near a hot surface are in more violent motion than those near a cold surface. A particle in this space will be more energetically bombarded on its side which is toward the hot plate and will consequently move toward the cooler plate. This phenomenon is of importance with very small particles, primarily. Larger particles are forced toward the cooler surface by a gas stream flowing in the opposite direction along the particle's surface. The surface of a large particle actually gets heated on one side and cooled on the other. Because the density of a gas decreases with temperature increase, a stream flows along the particle's periphery from the cooler to the hotter zone. The reaction to this flow forces the particle to the cooler zone. Thermal precipitation, as the application of the phenomena is called, has been used in sampling of aerosols. In fact, an instrument employing this principle and built according to a design developed at Georgia Tech is now being marketed nationally.

Aerosols also react to a sound field, and, as before the reaction depends on the size of the particle. Sound is, of course, a series of compression and rarefaction waves. When an aerosol is exposed to a sonic field, the particles tend to be moved back and forth at the frequency of the sound and at a velocity which varies with the size of the particle but which is always less than the velocity of motion of the gas phase. The large particles move least while the very small particles move almost at the gas velocity. The greater the intensity and the higher the frequency of the sound, the greater is the energy of impact and the more numerous the collisions; hence sonic means for destroying smoke, dust, fog, etc., have been studied widely. Com-

BY O.SOGLOW

TIRED OF BREATHING TIRES? Your lungs are, if you're a city dweller. Experts figure that tiny particles from rubber tires make up 40% of the dirt in city air. Other elements: coal soot, 30%; sand and grit, 20%; live bacteria, 10%.

BY O.SOGLOW

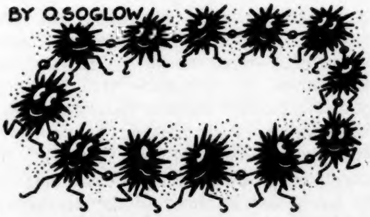


COLD WALLS CATCH DUST! Walls get streaked with dust and dirt if they're only one degree colder than the air in a room. Reason: warmer room air causes dust particles to settle. Experts report cold nail heads and plaster over metal laths are the best dust-catchers.

mercial utilization of sonic devices for this purpose has not been significant as yet, due, in part, to the annoyance human beings experience from the sound.

Light interacting with aerosols produces spectacular results. With natural aerosols, the effect is responsible for the colors of the rainbow and some of the colors of the sky. Very small particles, suspended in a transparent medium such as a gas, scatter blue light more than they do red light. Exposed to white light, i.e., light of all colors, such a system would appear reddish when seen with transmitted light and bluish with reflected light, regardless of the color of the aerosols material in bulk form. (It might be a shock to some smokers to see that blue-appearing tobacco smoke is, in reality, mostly water vapor and brownish oily droplets.) At dawn and again at sunset the sky in the direction of the sun appears red, while other portions of the sky are a deep blue. The effect is largely due to the dust and water vapor in the atmosphere near the earth's surface. At these particular times of day, the sunlight enters the atmosphere obliquely and therefore passes through a greater depth than at other times.

Inertial forces also affect aerosols. When aerosols are caused to flow in a curving duct, for example, inertial forces are manifest .The particles, being more dense than a similar volume of gas, tend to change direction the least. A separation between particles and gas, as well as between the larger and smaller particles, is thus brought about. At least two devices employing this basic principle have progressed to patent application stages.



DANCING CHAIN GANG! Look at particles of dust through a microscope and you'll see that they often form long flexible chains that twist and turn like groups of children holding hands. Electrical charges on the particles link them together.

WATCH MY DUST! A lump of charcoal the size of a pack of cigarettes has an area of about 22 square inches. But when you crush it to fine dust, its total area is increased to the size of a city block.

One odd property of aerosols should be mentioned. Everyone has observed this phenomenon although an excuse may be in order if it were not recognized as such. A gas will expand until it fills completely its container regardless of size. An aerosol, however, tends to maintain itself as an entity. A single white cloud floating in an otherwise blue sky is an example which everyone has seen. The efect is also occasionally observed in the laboratory. Just why this should happen is not understood. It probably is responsible for some of the discrepancies in reported data on aerosols.

In summary, the physical properties and the behavior of aerosols can vary widely depending on the condition to which exposed. By treating aerosols with due regard for the various effects outlined above, some success has been attained in cleaning impure air, in recovering materials which would otherwise be lost, in screening military operations, in protecting personnel from radiation danger, and in many other ways. Much is not understood about aerosols, and much remains to be done. This article, intended to be a rather general survey of the field, could only touch the high points. It leaves for a later paper unmentioned investigations dealing with aerosols of unique properties and their special applications.

Statistical Theory and Accounting

By John H. MacKay, Associate Professor, Industrial Engineering

RECENTLY, ACCOUNTANTS have begun to consider the use of statistics in connection with auditing and general accounting. This article briefly outlines those areas of auditing and accounting where statistical methods might be used profitably.

The general statistical decision problem involves a collection of random variables whose distributions depend on one or more unknown real numbers called parameters, and a set of decisions available to the experimenter. The decision preferred depends on the parameter values; that is, one decision may be preferred for some values, and another decision for other values of the unknown parameters.

A decision procedure is, for practical purposes, a division of all the possible values of the random variables into groups, one group corresponding to each available decision. When the observations are taken, they fall into one of the groups, and the decision is made which corresponds to that group. Corresponding to each decision made there is a loss to the experimenter (gain being recorded as negative loss), and for each decision the amount of the loss depends on the unknown parameters. The experimenter usually wants to choose a decision mechanism for which the loss is as small as possible.

Since the decision actually made depends on the random variables observed, the loss will generally be different from experiment to experiment. In other words, the loss itself is a random variable, and cannot be controlled in a single experiment. Over a large number of repetitions of the experiment, the "average" or expected loss is constant, and the experimenter usually concentrates on this. A small expected loss is associated with a desirable procedure. Occasionally a decision method will exist whose expected loss is smaller than that of any other method for all values of the unknown parameters. Clearly such procedure is "best." More often it turns out that one method has smaller expected loss for some parameter values, while a different method has smaller expected loss for other parameter values. In such cases the expected loss cannot be used as a criterion for choosing the "best" from a collection of decision procedures.

In order to choose a "best" rule it is usually necessary to select some function of the expected loss as a criterion. Such a function is often called the "risk" and is independent of the unknown parameters. An example of such a risk function is the maximum expected loss, taken over all parameter values. When the risk function has been chosen, the experimenter desires to select the decision mechanism with smallest risk, if one exists.

General Considerations

Any application of statistical theory to practical problems involves certain difficulties. One must first construct a statistical model in which the random variables, parameters, and distributions correspond to the measurable physical quantities, unknown constants, and probabilities of the actual problem. Some accounting problems do not readily lend themselves to statistical treatment. In auditing current liability balances it may be difficult or impossible to set up a suitable statistical model. However, the construction of a model is often relatively easy, and in most of the accounting applications suggested below such seems to be the case.

In all applications the chief problem is the choice of a suitable loss function. In cases where there is a single, well defined objective of the analysis, the

choice is difficult enough. In accounting applications the choice of loss functions may be more troublesome than in some other areas of application. To illustrate: in military statistical problems the object is usually to destroy the enemy as quickly as possible, while in an agricultural field experiment the aim may be to select the most effective of a number of fertilizers. An intermediate result in the solution of the military problem might be an estimate of the enemy position. In the field experiment estimates of the fertilizer effects are obtained. In both cases the estimates should be chosen so as to

Continued on page 22

A Typical Problem

Inventory Count

Suppose there is a warehouse containing N identical inventory items, and that a statistical estimate of N is required. One way to carry out the sampling is to divide the warehouse into m compartments or cells, and count the number of inventory units in k of the cells. Generally, $k < m$. It is assumed that the compartments are selected so that the chance of an item being stored in a particular compartment is the same for all compartments. Further, it is assumed that the chance of an item being stored in any cell does not depend on how many items are already in that cell. This assumption will be nearly satisfied in some cases of practical interest. Let S be the number of inventory items counted in the k cells.

The random variable in this problem is S and the unknown parameter is N. The available decisions are: $N = 1$, $N = 2$, etc. Without much loss of accuracy we may take the available decisions to be the non-negative real numbers. The required estimate is some function of S, say $t_0(S)$. One reasonable requirement is that, on the average, $t_0(S)$ should be equal to N. That is:

$$(1) \qquad E_N t_0(S) = N.$$

The loss from deciding that $N = t_0(S)$ should depend on the distance between N and $t_0(S)$. For instance, one might take the loss to be the square of the distance, $\{t_0(S)-N\}^2$. The expected loss in such case is simply the variance of $t_0(S)$, since $t_0(S)$ is unbiased as indicated by (1). The expected loss or variance is:

$$(2) \qquad V_N t_0(S) = E_N \{t_0(S)-N\}^2.$$

It turns out in this case that there is an estimate $t_0(S)$ which, for all N, has no greater expected loss than any other unbiased estimate. This is the "best" estimate and is given by:

$$(3) \qquad t_0(S) = S/p,$$

where $p = k/m$.

To prove the assertion (3), observe first that S has the binomial distribution:

$$P\{S=c\} = ({}_N C c) p^c (1-p)^{N-c} = f_N(c).$$

Define:

$$T = \{t(S)\colon E_N t(S) = N\},$$

$$g(s.N+1,N) = f_{N+1}(s) - f_N(s).$$

Then,

$$E_{N+1}\, g(S,N+1,N) = O,$$

(4)

$$E_{N+1}\, \{g(S,N+1,N)\}^2 = \frac{p}{(N+1)\ (1-p)}.$$

That t(S) is in T implies

$$(5) \qquad E_{N+1} \{t(S) g(S,N+1,N)\} = 1.$$

From (4) and (5), by the Schwarz inequality:

$$V_{N+1}\, t(S) \geqq \frac{(N+1)\ (1-p)}{p}$$

for all t(S) in T, where V indicates the variance. That is,

$$(6) \qquad V_N t(S) \geqq \frac{N(1-p)}{p}.$$

It is clear that the function $t_0(S)$ given in (3) is unbiased and attains the lower variance bound in (6). Hence $t_0(S)$ is the required minimum variance unbiased estimate.

The number k is at the disposal of the experimenter. In particular, k may be chosen so that the percentage of absolute error will be small with high probability. For arbitrary constant c and probability $b < 1$, k may be chosen so that:

$$P\left\{\frac{|t_0(S)-N|}{N} < c\right\} > b.$$

The last inequality may be satisfied less expensively than otherwise by selecting the cells for examination in a sequential manner.

maximize certain probabilities: the probability of destroying the enemy, and the probability of selecting the most effective fertilizer. In a balance sheet audit it may be desirable to determine the accuracy of accounts receivable balances as shown by the books. It is by no means clear what measure of "accuracy" should be used, and still less obvious what properties an estimate of this "accuracy" should possess.

After a suitable loss function has been defined there will usually remain the problem of choosing a function of the expected loss which is independent of the unknown parameters. In making the choice, accountants should experience no more difficulty than have others who use statistical methods.

Accounting Spheres of Statistical Interest

Ordinary statistical estimation has already been used in determining quantities of physical inventories for auditing purposes. Less attention has been paid to proper statistical estimation in connection with items like redeemable containers (assets) and unused coupons (liabilities). The estimation procedures now used have long histories and seem reasonable on intuitive grounds, but their properties have not been studied.

Apportionment of revenues has been done statistically in certain cases. The possibilities of apportioning costs to joint products on a sound logical statistical basis should be considered.

Sampling methods have been studied (again with respect to inventories) and might receive further consideration for the purpose of selecting the periods and records subjected to detailed audit. It would be advantageous to know what portion of the detailed audit should be devoted to the "cut-off" and how best to divide the rest of the effort. The selection of a time for internal or external "surprise audit" might best be left to a random device. The setting up of reasonable statistical models for receivable verifications should be undertaken. Such models might be difficult to work out, but considerable value would attach even to incomplete or approximate results.

Quality control techniques are available for maintaining high levels of accuracy in the accounts. One could control the quality of certain phases of the actual auditing process, using samples within samples. Any detailed checking or counting might be so controlled.

Cost quality control should also be undertaken so that when unit production costs exceed certain levels, for instance, remedial action may be taken as soon as possible. Computer calculations combined with statistics now make this feasible.

The notions of secular trend and least squares are available to auditors and could be used in determining the rate and direction of firm growth (of interest to possible investors in a company) and perhaps in the disclosure of irregularities. For instance, significant departures from trend in sales discounts, returned sales, bad debts, or cash sales, may indicate possible defalcations. Even a departure from the usual distribution among vendors in the purchases account may be significant.

Accounting, statistics, and mathematics together, the tools of the business operations analyst, are being used to some extent in determining optimum allocations of equipment (such as buses, aircraft and railroad cars), best locations (for instance of warehouses), as well as proper inventory and purchase plans. There has been a large amount of theoretical research done in these areas during the last decade, which may now be put to practical use with the aid of new analogue computers. Theoretical results concerning cycle and trend may be employed in estimating future demand, and adjustments of inventories and purchases made to anticipate this demand.

A large amount of work must be done before some of the above-mentioned ideas can be put into practice. New theoretical statistical results must be obtained and some presently existing theory tailored for accounting use. Accountants themselves can contribute much by precisely defining the objectives of their various activities, and accustoming themselves to thinking in terms of error probabilities, or more generally, of loss and risk functions.

Ingols, R. S. and L. T. Hilley, "What Are Reasonable Toxic Limits on Wastes Discharged to Sewers." Reprinted from Wastes Engineering, July, 1956. Reprint 103. Gratis.

This article discusses the problems faced in attempting to translate the theoretical results of toxicity studies into practical considerations for the establishment of codes and regulations to government the discharge of toxic materials into sewage treatment plants.

Chambers, H. H. and R. S. Ingols, "Copper Sulfate Aids in Manganese Removal." Reprinted from Water and Sewage Works, June, 1956. Reprint 104. Gratis.

This article describes how oxidation of manganese in a raw supply to insoluble oxides was relieved by treating with small dosage of copper sulfate to form soluble manganic dioxide.

Kethley, T. W., E. L. Fincher and W. B. Cown, "A System for the Evaluation of Aerial Disinfectants[1]." Reprinted from Applied Microbiology, Vol. 4, No. 5, September, 1956. Reprint 108. Gratis.

A method is presented for the evaluation of aerial disinfectants. This method, properly applied, is capable of yielding reproducible results expressed in a manner which can be applied universally. The equipment required is relatively inexpensive and is fabricated from generally available materials.

The modifying effect of relative humidity on the activity of aerial disinfectants is taken into consideration in this system, and compounds are offered as standards of reference in light to this effect.

Methods are given for the production of a standard bacterial aerosol, as are the details of equipment for diluting this aerosol, mixing it with chemical vapors, and sampling the resultant mixture.

Sugarman, Nathan and P. M. Daugherty, "Oxidation of Alpha-Pinene." Reprinted from Industrial and Engineering Chemistry, Vol. 48, Page 1831, October, 1956. Reprint 109. Gratis.

Pinic acid esters have potential uses as lubricants and plasticizers. Pinic acid is now prepared from pinonic acid produced by the permanganate oxidation of α-pinene. Its preparation by ozonolysis of α-pinene also has been studied.

A series of screening experiments employing peroxides and nitrogen-containing oxidants for the conversion of α-pinene to pinic and pinonic acids, and some further experiments using hydrogen peroxide with and without catalysts are described.

While some of the vapor-phase reactions with the nitrogen-containing oxidants were of interest and might warrant further investigation, the results of the screening tests indicated that hydrogen peroxide was the most promising oxidant of those treated. However, while pinic and pinonic acids are formed, the yields are generally low, and complex mixtures of acids are obtained.

Fetner, Robert H., "A Study of Factors Affecting X-Ray-Induced Chromosome Aberrations in the Microspores of Tradescantia paludosa. II. The Oxygen Effect." Reprinted from Radiation Research, Vol. 5, No. 4, October, 1956. Reprint 110. Gratis.

The microspores of *Tradescantia paludosa* were X-irradiated with 200 r and 400 r in atmospheres of helium, air, and oxygen, and the number of chromosome aberrations and deletions produced were recorded. The reduction in aberration frequencies with decreasing concentrations of atmospheric oxygen was found to be in good agreement with the results of other workers. The data suggest that when irradiations are performed in the absence of oxygen (in helium) there is less rejoining of initial breaks than when oxygen is present.

There and other technical publications may be obtained, and the complete publications list requested, by writing Publications Services, Engineering Experiment Station, Georgia Institute of Technology, Atlanta 13, Georgia.

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edited in retrospect

the changing scene

•A great deal of space in this issue is devoted to Tech's Increasing capabilities to carry out research. The new Mechanical Engineering Laboratory, the improved Aeronautical Engineering research facilities, the Industrial Products Laboratory and others were presented to you in detail for the first time on the preceding pages.

At the bottom of this page is the beginning of still another new Tech facility for research. It is, or will be in one month, a variable-sloped flume. It was designed for Tech's rapidly-expanding Hydraulics Laboratory by the head of the laboratory, Regents Professor Carl Kindsvater and Research Engineer Tom Elliott and Research Assistant John Steinichen of the Engineering Experiment Station.

The new flume, capable of being tilted to maintain a constant depth and uniform flow over its entire 90-foot length, will be used for basic investigations of uniform flow in open channels with varying degrees of roughness and various shaped cross-sections. The work will be done for the U. S. Geological Survey who has supported Tech's open-channel research since its inception. Tech, the pioneer research agency for the Surface Water Branch of USGS, has been so successful in its program that USGS is now supporting research in this field at various other institutions. Proof once again that successful research begats more research.